Tools to Compare Diving-Animal Kinematics with Acoustic Behavior and Exposure

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LONG-TERM GOALS

Intense international concern has arisen over the potential effects of anthropogenic sound on protected marine wildlife. To study this issue presents a challenge, however, because research animals in captivity form a limited sample set that may not always be appropriate to extrapolate to wild populations, and because most marine species spend the majority of their time submerged and out of sight of researchers. Thus instrumentation capable of monitoring free-ranging marine animals is an essential foundation for research on sound and marine wildlife.

Tags, attached to marine mammals are being increasingly used to understand their underwater behavior. Typically these tags contain a package of instruments including accelerometers, magnetometers, a pressure sensor and a hydrophone. The goal of this project is to make the interpretation of this data more straightforward for scientists studying marine mammal behaviors.

OBJECTIVES

TrackPlot is a software package developed at the University of New Hampshire designed for the kinematic analysis data from tags attached to marine mammals, such as Johnson's DTAG[1]. At the starting point of the grant, however, the software was little more than a promising prototype. The task for the UNH component of this project has been to transition this software into a general purpose tool for dive and kinematic pattern analysis, add integrated capabilities for acoustic analysis, and add support for multiple tags, especially the new Acousonde from Greeneridge Sciences [2]. In addition, we also proposed to make trackPlot software robust, improve its user interface, properly document it, and release it for multiple operating systems. Substantial progress has been made towards meeting these objectives.

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14. ABSTRACT
Intense international concern has arisen over the potential effects of anthropogenic sound on protected marine wildlife. To study this issue presents a challenge, however, because research animals in captivity form a limited sample set that may not always be appropriate to extrapolate to wild populations, and because most marine species spend the majority of their time submerged and out of sight of researchers. Thus instrumentation capable of monitoring free-ranging marine animals is an essential foundation for research on sound and marine wildlife.

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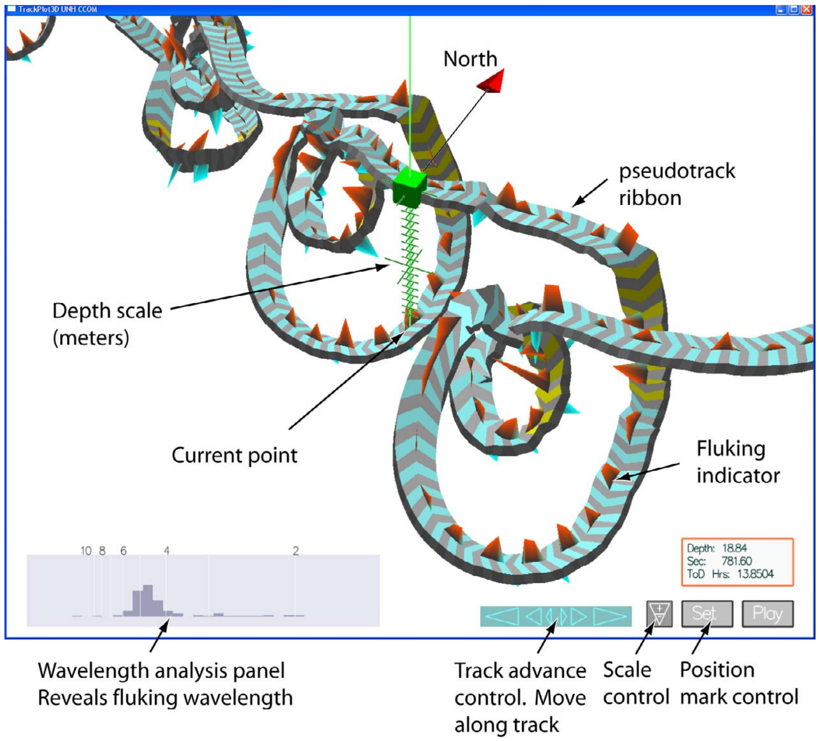

Figure 1. Various features of the trackPlot display are illustrated including the ribbon track, the fluking indicator (based on differentiating the track about a lateral axis in animal coordinates) and an auxiliary plot of showing fluking intervals.

APPROACH

The approach used is a spiral software development model. Software is continuously develop and refined to meet the needs of both marine mammal researchers and tag hardware developers. Although UNH has not yet taken delivery of an Accusonde tag, development has been possible because of the PI's participation in the April-June Antarctic MISHAP cruise (Nowacek, PI). This project used DTAGs rather than Acousondes, but because the instrumentation package is essentially identical, development for one platform should directly apply to the other.

WORK COMPLETED

Integration of acoustic data handing. TrackPlot now has the capability to display an acoustic spectrogram along with the pseudo-track, and has an integrated capabability of providing an estimation of the animal's speed, using the method of Goldbogen [2]. See Figure 2 for examples.

Graphical user interface development. Previously, trackPlot user commands were given by individual keystrokes on a qwerty keyboard. Different keys allowed the user to advance forward and backwards, and zoom in or out. TrackPlot has now been given an interactive control panel as well as on-screen buttons for some of the more common interactions. Various features of this user interface are illustrated in Figure 1. These include the ability to advance forward and backwards along the track as well as rotate relative to the viewpoint. The play button results in the animal smoothly advancing along the track. The zoom widget magnifies and minifies the view depending on the level of detail that is required.

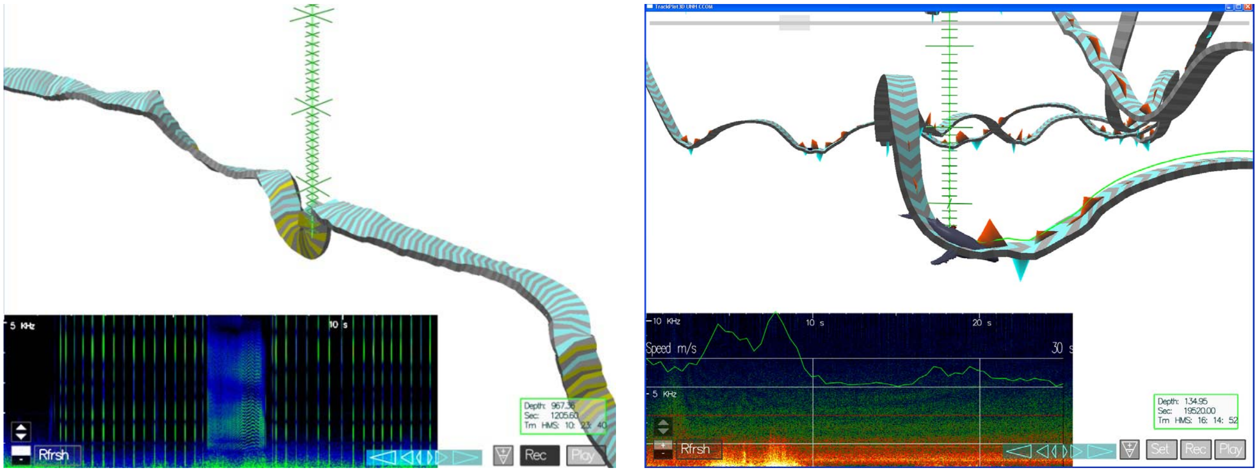

Figure 2. Left: The acoustic spectrogram from a beaked whale foraging at 967m depth revealing clicks and buzzes. Data courtesy of Brandon Southall. Right: The typical acoustic signature of a lunging humback feeding on krill. The overlaid plot shows speed estimated from flow noise.

Integrated analysis and plotting capabilities. In addition to the acoustic spectrogram plots trackPlot can display a variety of time series plots facilitating a greatly speeded analytic process. Illustrated in Figure 3(left) is a plot showing data from a Florida manatee (data courtesy of Douglas Nowacek). The insert plot shows the results of a fourier analsis of the residual accelerations, once g has been subtracted. This gives an accurate indication of the fluke rate for a Florida Manatee with a tag attached to its peduncle. TrackPlot can also estimate fluke rates from differentiated pitch changes and this has been found to be effective for humpbacks. In addition, trackPlot can display residual accelerations directly, as well as rate of descent and estimated speed from flow noise as shown in Figure 3(right).

Basic dive statistics. On loading a pseudo-track, trackPlot automatically generates a depth histogram for the entire dive giving the percentage of time the animal spent at different depths. In addition, trackPlot enables the user to save data from individual point or selections of track for more detailed analysis. For example, depth histograms can be generated for selected sections of track.

Automatic kinematic feature finding. A number of approaches to automatic feature finding have been explored. The most successful of these to date has been the development of a feature detector to automatically find humpback lunges from the flow noise signatures. This has been validated against human judges and been used to automatically find lunges in the tracks of 6 animals foraging in and around Wilhemena Bay in the West Antarctic Peninsula [3].

Based on the experimental work done so far, a robust template feature finding is planned allowing the user to choose a particular track section as a template and a set of variable such as one or more of : descent rate, rate of turn, estimate speed. The program will then search the entire track for matching features, and print out their locations, as well as other characteristics.

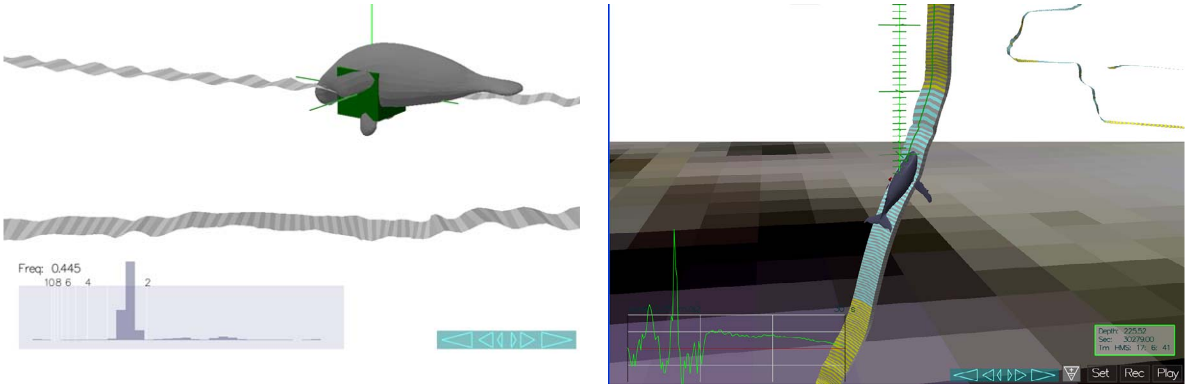

Figure 3. Left: A trackPlot image of a Florida Manatee. The insert shows one of the plot options based on a fourier analysis of the residual accelerometer data. Right: The inset plot shows the residual acceleration attributable to a vertical lunge by a Humpback.

Pseudo-track creation: TrackPlot now has the ability to import raw data from a set of accelerometer, magnetometer and pressure sensors and to construct a pseudo-track using an intuitive interactive technique. The user only has to specify a section of track where the animal can be assumed to be horizontal, and a section of track containing a deep dive and a pseudo-track is automatically created.

This class of tag inherently is incapable of providing direct estimates of speed. (The accelerometer information is used to determine the animal's attitude and it cannot also be used to estimate accelerations, except under special circumstances.) Nevertheless, under some circumstances, speed can be inferred from the available data. First, when the animal is ascending or descending steeply, if we assume that the animal is traveling a rostral direction, we can then simply divide the rate of ascent by the sine of the pitch angle to get speed. This method is used in pseudo-track creation.

We have also developed a correction to obtain a better estimate of pitch angle, acceleration in the rostral direction, and speed in the rostral direction. The basis for the correction is illustrated in the left hand diagram shown in Figure 4. The correction is based on the observation that the measured acceleration can be described as a vector sum of gravity and the acceleration of the animal in its direction of travel. The vector w represents the actual acceleration of the animal in a rostral direction, g represents gravity and a represents the vector sum of these. This is the vector that is actually measured by the tag. The values of a, g and θ are known. We can calculate w – the estimated acceleration of the whale in a rostral direction, and α – the correction to the pitch angle.
The second method, which has already been briefly discussed, is to use low frequency flow noise, recorded from the tag, to estimate speed [3]. Low frequency flow noise is highly correlated with speed and this can be used to estimate the animal's speed through the water. The capability of applying this to pseudo-track creation is still under development, but we have already used it in identifying lunges.

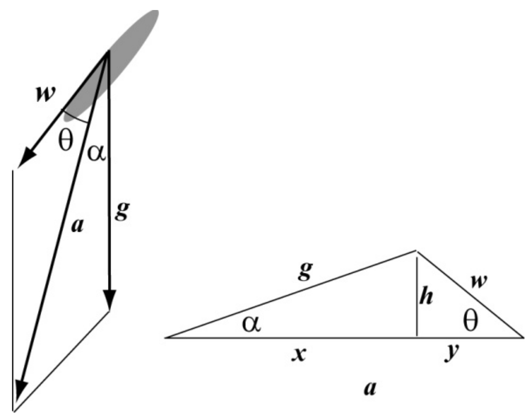

Figure 4. a : accelerometer vector . w: whale acceleration. g: gravity vector. θ: the measured angle of the whale with respect to the gravity vector. α: the angle correction. The ellipse represents the attitude of the whale.

Georeferencing Pseudo-Tracks: A basic pseudo-track is essentially a sequence of dead-reckoned positions constructed relative to a starting point. Basic georeferencing can therefore be accomplished by tying the starting point to a geographic location. In many instances, however, a set of fixes may be available, obtained from laser range finders relative to a GPS position, or simply from visual estimates of range and bearing. It is straightforward to tie a pseudo-track to a set of fixes, using linear interpolation, but because of inaccurate speed estimation this often results in a severely distorted track.

In order to improve the quality of a geo-referenced pseudo track, relative to a set of fixes we implemented a simple dynamic model of animal speed with two parameters. Using the fluking estimated from pitch accelerations, we drive the animal model forward with a force proportional to the amplitude of the strokes. A second force slows the animal proportional to the square of the speed. TrackPlot attempts to optimize this model by adjusting two parameters, one controlling the acceleration, the other the deceleration, using a simple hill-climbing method. Finally, small adjustments, of a few cm/sec at most are added to “drift” the animal towards the fixes. This deals with inaccuracies due to currents and other unaccounted for factors. Figure 5 shows an example of a georeference track generated despite gaps between fixes of up to 8 hours.

RESULTS

As a result of this grant, trackPlot is a far more capable and robust piece of software. The most important new capabilities are: (1) a method to construct a pseudo-track from raw data, using a straightforward graphical interface; (2) its ability to read acoustic files and display spectrograms referenced to track locations; (3) its ability to georeference a pseudo-track to a set of surface fixes; (4) its ability to find features, in particular, lunges; (5) a graphical user interface and written documentation. These features have been field tested in an extensive Antarctic cruise using data from tagged humpbacks, as well as with data from Florida manatees and Mediterranean Beaked whales. A paper currently in preparation reports on Antarctic humpback lunges finding based on an automatic filter that is built into trackPlot.

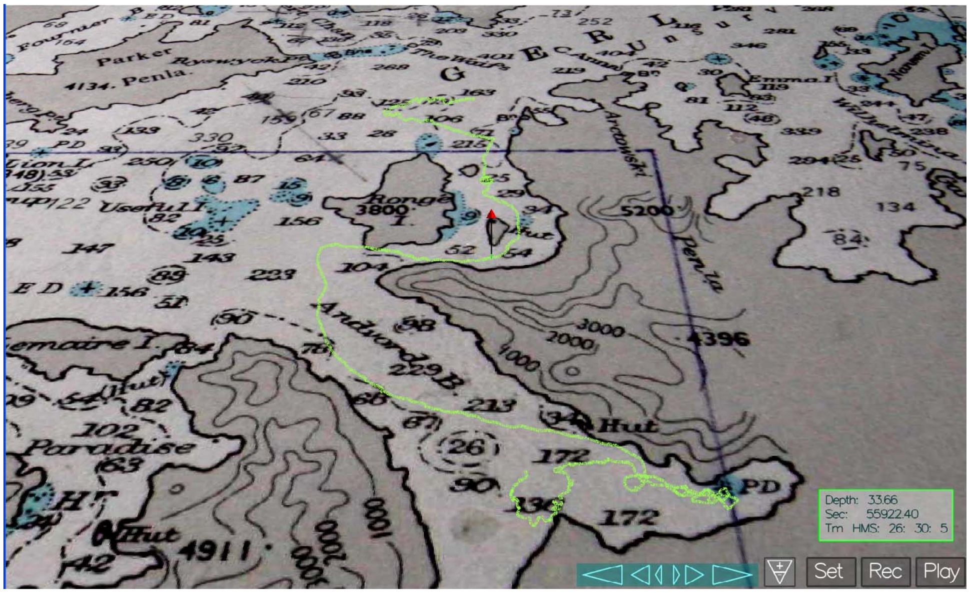

Figure 5. A georeferenced pseudo-track from an animal tagged in Andvord Bay Antarctica. For most of the 24 hour period of tag attachment, no fixes were obtained because of lack of visibility during the 16 hour late fall night.

IMPACT/APPLICATIONS

The larger goal of this project has been to make the interpretation of tag data more straightforward for scientists studying marine mammals. The developments described in this report have taken it a long way towards achieving this goal.

RELATED PROJECTS

The present work is a collaborative effort with William Burgess, the creator of Acousonde, separately supported under Award number N00014-09-C-0406

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